

EDGE AND BEVEL CLEANING PROCESS AND SYSTEM

INVENTORS:

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RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Serial No. 10/051,755 filed on January 15, 2002 (NT-210) and U.S. Patent application Serial No 10/041,058, Vertically Configured Chamber Used for Multiple Processes, (NT-005D) filed December 28, 2001 which is a continuation of US Patent No. 6,352,623, all incorporated herein by reference.

FIELD

[0001] The present invention generally relates to semiconductor processing technologies and, more particularly, to a system and process that removes a conductive layer from the edge and/or bevel of a work piece.

BACKGROUND

[0002] In the semiconductor industry, various processes can be used to deposit and etch conductive materials on the wafers. Deposition techniques include processes such as electrochemical deposition (ECD) and electrochemical mechanical deposition (ECMD). In both processes, a conductor is deposited on a semiconductor wafer or a work piece by having electrical current carried through an electrolyte that comes into contact with the surface of the wafer (cathode). A detailed description of the ECMD method and apparatus can be found in U.S. Patent 6,176,952 to Talieh entitled "Method and Apparatus For ElectroChemical Mechanical Deposition", commonly owned by the assignee of the present invention.

[0003] Regardless of which process is used, the work piece is next transferred to a cleaning and drying station after the deposition step. During the cleaning steps, various residues generated by the deposition process are rinsed off the wafer, and subsequently the wafer is dried by spinning and if necessary blowing nitrogen on its surface. In one design, the ECD or ECMD chamber and the rinse chamber can be stacked vertically in a vertical process chambers arrangement. In this arrangement, the plating process can be performed in a lower chamber, and

the cleaning and drying can be carried out in an upper chamber after isolating the upper chamber from the lower chamber. One such vertical chamber is disclosed in the co-pending U.S. Patent 6,352,623 entitled "Vertically Configured Chamber Used for Multiple Processes," commonly owned by the assignee of the present invention.

[0004] Conventionally, after the plating process is performed to deposit the conductive material, the work piece may be polished mechanically and chemically, e.g., chemical mechanical polishing (CMP), to remove overburden conductive material from the front face of the work piece. As is known, the material removal can also be carried out using chemical etching or electrochemical etching. In electrochemical etching or electrochemical polishing, the wafer is made anodic (positive) with respect to an electrode after completing an ECD or ECMD process.

[0005] Copper is a preferred conductive material that can be deposited by ECD and ECMD processes. Therefore it will be used as an example. As a result of electroplating process, copper may be deposited on the edges and sides, i.e., bevel, of the wafer where no ICs or circuits are located. Such remaining copper, which is often referred to as the edge copper, may migrate to neighboring active regions from the sides and edges of the wafer, especially during annealing steps. Further, copper from a wafer edge may contaminate the wafer transport system, and so be passed on to contaminate other wafers. For this reason, it is important to remove the copper from the edges and the bevel of the wafer following each copper plating process step.

[0006] To this end, there is a need for removing edge copper in copper plating processes in an efficient and effective manner with high throughput.

SUMMARY OF THE INVENTION

[0007] It is an object of the present invention to provide a method and apparatus for removing an edge conductor that exists on a workpiece.

[0008] It is a further object of the present invention to provide a method and apparatus for removing an edge conductor in a vertically configured chamber that also performs electroplating, cleaning and drying.

[0009] It is a further object of the invention to provide a method and apparatus for removing an edge conductor using at least two streams of etchant applied to the edge of a workpiece.

[0010] It is a further object of the present invention to provide a method of removing conductive material from an edge region of a workpiece, which is applied subsequent to an electrochemical process. The edge region includes a front edge surface, a back edge surface and a bevel. During the removal process, as the wafer is rotated, a first etchant flow is directed onto the back edge surface of the workpiece while a second etchant flow is directed onto the front edge surface of the workpiece. Rotating the workpiece results in outwardly directing the etchant, which is delivered by the first and the second etchant flows, to the bevel and thereby causing removal of the conductive material from the edge region of the workpiece.

[0011] The above object of the invention, among others, either singly or in combination, are achieved by the present invention by providing at least two nozzles that deliver an etchant at an edge region of a rotating substrate. The at least two nozzles are located in an upper chamber of a vertically configured processing subsystem that also includes mechanisms for plating, cleaning and drying in upper and lower chambers.

[0012] These and other features and advantages of the present invention will be described in more detail below with reference to the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The above and other objectives, features, and advantages of the present invention are further described in the detailed description which follows, with reference to the drawings by way of non-limiting exemplary embodiments of the present invention, wherein like reference numerals represent similar parts of the present invention throughout several views and wherein:

[0014] Figure 1 illustrates a wafer on which edge removal is performed according to a first embodiment of the present invention;

[0015] Figure 2 illustrates a cross section of a wafer on which edge removal is performed according to the present invention;

[0016] Figure 3 illustrates a more detailed cross section of a portion of a wafer on which edge removal is performed according to the present invention;

[0017] Figure 4 illustrates a more detailed cross section of an edge portion of a wafer on which edge removal is performed according to the embodiment to the present invention;

[0018] Figure 5 illustrates a vertical chamber in which edge removal is performed according to one embodiment of the present invention;

[0019] Figures 6 and 7 illustrate the edge removal apparatus of one embodiment of the present invention in further detail;

[0020] Figure 8 illustrates an edge portion of a wafer that has had copper removed therefrom according to the present invention;

[0021] Figure 9 illustrates an edge conductor removal process and apparatus using two etchant flows according to a second embodiment of the present invention;

[0022] Figure 10 illustrates removal of the edge conductor from an edge region of the workpiece;

[0023] Figure 11 illustrates the edge region shown in Figure 10 after the edge conductor is removed;

[0024] Figure 12A illustrates an embodiment of an edge conductor removal system having two integrated front and back nozzles;

[0025] Figure 12B illustrates another embodiment of the edge conductor removal system having separate front and back nozzles; and

[0026] Figure 12C illustrates the tilt angle of the front nozzle with the front surface of the wafer.

DETAILED DESCRIPTION

[0027] The present invention provides a method and apparatus to remove unwanted conductive material from an edge region of a workpiece. The unwanted conductive material removal process is applied subsequent to an electrochemical process to deposit a copper layer on a surface of a workpiece. The edge region, which has the unwanted edge material, includes a front edge surface, a back edge surface and a bevel. In the preferred embodiment of the present invention, during the removal as the workpiece is rotated, a stream of etchant solution from a front edge nozzle is delivered to the front edge surface of the workpiece while another stream is delivered to the back edge surface from a back edge nozzle. Rotational motion of the wafer directs the etchant, which is delivered by the front and back edge nozzles, to the bevel and thereby causing removal of the unwanted conductive material from the edge region of the workpiece.

[0028] Figure 1 is a top plane view of a plated work piece 100 such as a semiconductor wafer. As also shown in Figure 2 in side view, the plated wafer 100 comprises a top layer 102

having a top surface 103, a bottom layer 104 having a bottom surface 105, a top surface edge 106 and a wafer side 108 or bevel around the perimeter of the wafer surfaces 103 and 105. In this embodiment, the top layer 102 of the plated wafer 100 is comprised of a layer of electroplated conductive material, for example copper, and the bottom layer 104 is comprised of a semiconductor substrate, such as a silicon substrate. In this embodiment copper is electroplated on the substrate 104 using ECMD or ECD processes.

[0029] Figure 3 is an enlarged partial cross-sectional view of near top surface region 109 of the wafer 100, shown in Figure 2, which comprises a via and a trench feature 110 and 112 formed in an insulating region 114 which is previously formed on the wafer surface. As shown in Figure 3, the surface region 109 of the plated wafer 100 may comprise a plurality of via, trench and other features such as dual damascene features. The features 110, 112 and the surface of the insulator between the features may be lined with a diffusion barrier/glue layer 116 and a seed layer 118, i.e., copper seed layer for the case of copper deposition. In most cases, the barrier layer 116 and/or the seed layer 118 extends onto the top surface edge 106, and sometimes onto the wafer side 108. In fact, one or both of these layers may wrap around and coat portions of the bottom surface 105 that is adjacent the wafer side 108. Since, during the electroplating, copper only deposits on the conductive regions that are coated with barrier or copper seed layer or with a barrier/seed composite layer, this, in turn, causes copper to deposit on the edge 106, the side 108 and the bottom surface 105. Electroplated copper layer 102 fills the vias 110 and the trenches 112 and forms the interconnect structure of the wafer 100, after the CMP process that removes the excess copper and the barrier layer from the top surface of the insulating region 114, therefore electrically isolating the copper regions within the various features. The interconnects are used to electrically connect different active portions and levels in the chip or IC.

[0030] As mentioned above, the copper layer 102 may also extend onto the side 108 and even the bottom surface 105 adjacent the edge 106, and thus forming an unwanted copper region 120 shown in Figure 4. The edge copper 120 may form around the circumference of the wafer 100. As exemplified in Figure 4, the edge copper 120 may have an upper portion 122, a side portion 124 and a lower portion 126. The edge copper portions 122-126 can be removed from the top surface edge 106, side 108 or bevel and bottom surface 105 by applying a copper etching solution through the process of the present invention. Although, in this embodiment, the edge copper is exemplified using the upper, side and lower portions, it is understood that this is for the

purpose of exemplifying the problem; consequently, the unwanted copper may just have the upper portion.

[0031] It should be noted that even in the case where copper may not be deposited in the regions 106, 108 and 105 of Figure 4 during the plating step, presence of the copper seed layer in those areas may exist and is typically undesirable. And a conventional CMP step carried out after the plating step may be able to remove any copper in the edge 106, but would not be effective in removing copper from the side 108 and the bottom surface 105.

[0032] The copper layer 102 may be deposited on wafer 100 using an electroplating process and system 200 shown in Figure 5. The system 200 may be a vertical chamber comprising a lower section 202 and an upper section 204. As mentioned above, one such vertical chamber is disclosed in U.S. Patent No. 6,352,623, entitled "Vertically Configured Chamber Used for Multiple Processes.

[0033] Accordingly, according to this embodiment, an edge copper removal process is performed within the upper chamber. Thus, while the lower chamber will comprise some type of plating section, preferably comprise an ECMD process section but also a conventional ECD process section, the upper section will contain a cleaning and edge copper removal and drying section. The upper and lower sections have a movable barrier, described in one specific embodiment as guard flaps, which keep the various materials and solutions used in the processes of the upper chamber from reaching the lower chamber, as described further herein. In one embodiment of the process, an ECMD process is initially performed in the lower section 202, and in the following stage of the process, a cleaning by rinsing may be performed in the upper section 204. As will be described more fully below, after the cleaning, in the upper section 204, an edge copper removal process is performed. The edge copper removal process is followed by a second cleaning and drying process.

[0034] A wafer holder 206 supports the wafer 100 as deposition process is performed in the lower section 202. The wafer holder may comprise, preferably, circular chuck 207 upon which the wafer 100 is loaded, bottom surface 105 first (see Figure 2), and secured. Guard flaps 208 via linkage shafts/rollers 210 are positioned vertically such that the wafer holder 206 using a shaft 212 can be lowered into the lower section 202. The shaft 212 is further adapted to move side to side and to rotate about the vertical axis of the shaft 212. During the cleaning, edge

copper removal and drying, the wafer holder 206 is raised vertically into the upper section 204 and the flaps 208 are closed by moving them in the direction of the arrows 214.

[0035] During the ECMD process, as mentioned above, copper is applied in vias, trenches and/or other desired features in the wafer 100 (see also Figure 3) to form a generally flat copper layer over the features. An ECMD apparatus 215 may comprise a pad assembly 216 having a pad 217 placed on an anode 218 for depositing the copper on the wafer 100 while the wafer 100 is polished. The copper can be applied using an electrolyte solution.

[0036] As shown in Figures 6 and 7, after the deposition takes place in the lower section 202 of the system 200, the wafer holder 206 is raised using the shaft 212 to approximately its uppermost position. Then, the flaps 208 are moved from their vertical position to their horizontal position to separate the lower section 202 from the upper section 204. Once the flaps 208 are in closed position the cleaning is carried out. During the cleaning by rinsing, the holder 206 may be lowered towards the flaps 208.

[0037] A conventional cleaning solution, depicted by the arrows 222, may be provided through nozzles 224 which are located on the side walls 226 of the upper section and/or on the flaps 208. Used cleaning solution is drained out of the section 204 using outlet channels 228 along the side walls 226. This solution does not mix with the electrolyte in the lower section 202 due to the presence of the flaps 208 in the closed position. During the cleaning step, the wafer 100 is rotated and the cleaning solution is applied to the wafer 100. The wafer 100 may be spun dried by rotating the wafer at high rpm. Additionally, clean and dry air or inert gas like nitrogen may also be blown on the wafer to help dry it. After the cleaning and optionally drying processes, edge copper removal process is performed in the same upper chamber 204.

[0038] Referring to Figures 4, 6 and 7, during one embodiment of the edge copper removal process, a conventional etching solution, depicted by the arrow 230, is applied on the edge 106 of the wafer while the wafer 100 is rotated at approximately 20 to 1000 rpm, preferably at 50 to 500 rpm. Etching solutions are typically acidic and oxidizing solutions, which oxidize copper and remove it at a high rate. Generally, the etching rate may vary depending on the process time, temperature and the chemical composition of the etching solution. The etchant is applied in the form of a well regulated stream through at least one nozzle 232 that is preferably mounted on the flaps 208 or otherwise located relative to the wafer 100 such that the nozzle 232 directs a stream of the etching solution toward the wafer 100 in a manner that the stream has a

horizontal component that is directed away from the center of the wafer 100, thus assisting with keeping the etching solution away from the central portion of the wafer and at the edge 106 of the wafer 100.

[0039] The etching solution can be fed to the nozzle 232 through a feed tube 234 that is connected to a feed pump (not shown). The nozzle 232 directs the solution to the edge 106 as a tightly controlled stream of etching solution. The etching solution can be applied in various amounts for various periods of time, preferably in a range of 1 to 10 ml per second for approximately 5 to 20 seconds. Owing to both centrifugal force generated by the spinning wafer and the surface tension of the etchant, the etching solution arrives at the edge 106 at an angle and the stream of etchant that is outwardly directed to the upper portion 122 of the edge copper 120 flows over the portions 124 and 126 of the edge bead 120 and covers them. The angle at which the etching solution strikes the edge 106 can also be varied, which allows for narrowing or broadening of the etched region. Etched region width can also be changed by moving the wafer and/or the nozzle laterally or vertically. If the nozzle is constantly kept at a given angle, the etched region may be narrowed or broadened by moving the wafer up and down or moving it laterally. Similarly if the wafer is kept in the same lateral position and same elevation (but rotated), the etched region can be broadened or narrowed by varying the angle of the nozzle with respect to the wafer. As long as the above given process works in the manner described, the nozzle may be positioned on the walls or other places, and within the scope of the invention. As shown in Figure 8, accordingly, the etching solution etches and removes the edge copper portions 122-126 from the edge 106, side 108 or bevel and the bottom surface 105. In order to increase the etch rate, during the process, the etching solution or the wafer 206 or both may be heated approximately to a temperature less than 100°C, preferably 40-60°C. Heating of the etching solution or the wafer increases the etch rate and may also assist the following drying step that follows rinsing step. After the etching process, the wafer is cleaned and dried.

[0040] In another embodiment of the present invention, the etching solution or etchant may be delivered to the edge of the wafer using at least two etching solution flows. The etching solution flows may be directed towards the edge of the wafer as etching solution streams to remove edge copper from edge region of the wafer. In this embodiment, a first etching solution stream may be delivered to the back edge surface of the wafer and a second etching solution stream may be delivered to the front edge surface of the wafer. As the wafer is rotated, the

solutions are delivered and they wrap around the bevel of the wafer, thereby removing all the copper from the edge region including, front edge, back edge and the bevel.

[0041] As shown in Figure 9, wafer 300 is held by a wafer carrier 304. The wafer 300 comprises a back surface 301 and a front surface 302, which comprises a copper layer 303. The wafer carrier 304 may rotate and move laterally as well as vertically. In this embodiment, an edge region 305 of the wafer 300 is processed by a first etching solution stream 306 and a second etching solution stream 308. The first etching solution stream 306 is delivered by a first delivery device 310 or a first nozzle and the second etching solution stream is delivered by a second delivery device 312 or a second nozzle. The first and second nozzles 310 and 312 may be an integral part of an edge material removal device 314 or they may be formed as separate devices (see Figure 12B). Edge material removal device 314 receives the etching solution 315 or etchant from an etching solution supply tank (not shown) through the solution line 316.

[0042] Figure 10 shows edge region 305 in detail, which includes a front edge surface 318, a bevel 320 and a back edge surface 322. As shown cross-hatched in Figure 10, the edge region includes an edge copper 324, which will be removed with the process of the present invention. The edge copper 324 is formed around the edge region 305 because of a previous deposition step, which may be an electrochemical or electrochemical mechanical process step. It should be noted that the copper layer thickness at the edge region 305 may be high (0.5 micron or larger) especially for wafers deposited using a full-face plating machine where the whole front surface and edge of the wafer are exposed to a plating solution.

[0043] The removal process may be performed in the upper chamber of the vertical chamber system 200 described above although the invention may be practiced in any other edge copper removal chamber. For the case of vertical chamber geometry, the edge material removal device may be fixed on the inner walls of the upper chamber or on the flaps described in the above embodiments. In an exemplary process, the wafer 300 is first copper plated in the lower chamber and then taken into the upper chamber to remove edge copper. A cleaning process followed by a spin dry may be applied before the edge copper removal. After the cleaning and drying, edge region of the wafer 300 is placed between the first and the second nozzles 310, 312 of the material removal device to apply first and the second streams 306 and 308 of etchant to the wafer. The first stream 306 is delivered over the back edge surface 322 and the second stream 318 is delivered over the front edge surface 318. Delivery of the second stream 308 is performed

such that the second stream is either directed away from the center of the front surface 302 or the direction of delivery is near-tangent to the edge of the wafer (see Figures 12A and 12B).

[0044] Selection of such delivery direction protects the front surface of the wafer, which has electronic circuits, from splashes of the etchant, thereby preventing material removal from places other than the edge region. For the first nozzle 310, direction of the etchant stream is not critical since there are no circuits in the back of the wafer. The etchant should be delivered to the back edge surface 322 to maximize its removal rate. As the wafer is rotated, etching solution from both streams wraps around the bevel region and removes the edge copper 324 from the front edge surface 318, back edge surface 322 and the bevel 320 effectively as shown in Figure 11.

[0045] An exemplary arrangement of the first and second nozzles 310 and 312 can be seen in Figure 12A, which shows a bottom view of the wafer 300. As shown in Figure 12A, the second nozzle 312 and the second etchant stream 308 is directed towards the front edge surface 318 of the wafer 300. Etching solution flow rate from both nozzles can be controlled by utilizing a control valve (not shown) attached to the supply line 316. Further, by increasing or decreasing the nozzle size, different flow rates from different nozzles can be obtained. As long as it is directed towards the front edge surface 318 and away from the rest of the copper on the front surface 302, the stream 308 may be directed under any angle from a radial direction to a tangent direction. During the process, the nozzle 312 may be placed in a tilted position to increase effectiveness of the etchant delivery to the front edge surface 318. As shown in Figure 12C, the angle α (take off angle) between the front surface 302 and the direction of the stream 308 from the nozzle 312 may preferably be between 0° and 45° .

[0046] Figure 12B in bottom view shows an alternative nozzle arrangement. In this embodiment, a first nozzle 320 and a second nozzle 322 are separated and are fed by solution supply lines 324 and 326. The first nozzle 320 delivers a first stream 328 to the back edge surface 322 and the second nozzle 322 delivers a second stream 330 to the front edge surface 318 but away from the delivery point of the first stream. In this embodiment, etching solution flow rate from the first and the second nozzles may be controlled, i.e. reduced or increased, by utilizing valves (not shown) attached to the nozzles or supply lines. Thus, each nozzle may have a different flow rate. Further, in this embodiment, the solution supply lines 324 and 326 can be connected to the same etching solution supply tank or etching solution supply tanks. For both

embodiments, as the etching solution is delivered, the wafer may be preferably rotated in the direction of arrow A although it may also be rotated in the reverse direction. During the edge copper removal process, the etching solution delivery to the front edge surface and the back edge surface may be performed using a plurality of nozzles and a plurality of etching solution streams.

[0047] Although various preferred embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications of the exemplary embodiment are possible without materially departing from the novel teachings and advantages of this invention.